

THE ACID-BASE BALANCE OF THE BODY *

Its Relation to Health and Disease

The Acid-Base Balance of the Body.—Until recent years little consideration was given to the question of the acidity or alkalinity of body fluids. But of late the importance of maintaining or restoring the acid-base balance in the prevention and treatment of disease has become a major problem of physiological and clinical research.

Progress in this direction has been so rapid that a new field may be said to have opened to the clinician, based on a greater knowledge of the chemistry of the body.

In this connection certain terminology has been inherited by us from our misinformed ancestors and a number of new terms has arisen to meet the newer knowledge. Some confusion has naturally followed, to overcome which it is necessary to become familiar with new words and phrases as well as to understand more thoroughly the action of salts, bases and acids in health and disease.

Terminology.—The body consists essentially of proteins, fats, carbohydrates, inorganic salts, carbon dioxide and water—the latter constituting at least 75 per cent of the total body weight (1). The percentage of any class of constituents in the body is fairly constant at all times.

Electrolytes and Ions.—It has been found that many inorganic salts, bases and acids in solution are capable of transmitting an electric current. Such substances are termed "electrolytes."

This ability to carry an electrical current is satisfactorily explained by the Ionic Theory, which hypothesizes that in a solution of electrolytes a process of dissociation takes place, the molecule being broken down into ions, one class of ions carrying a positive charge and other ions carrying a negative charge of electricity. Thus in the case of sodium chloride, for example, there would be present in the solution:

- (a) sodium chloride molecules, carrying no charge;
- (b) sodium ions, carrying a positive charge;
- (c) chloride ions, carrying a negative charge.

Acids and Bases.—The behavior of acids, bases and salts in water solutions is due to the activities of their ions. In this connection, two types of ion are especially involved, namely *hydrogen ion* and *hydroxyl ion*. If the hydrogen ions are in excess of the hydroxyl ions, a solution is acid; if fewer, the solution is alkaline.

Dissociation.—Some acids and bases are spoken of as "strong," while others are described as "weak." The essential difference lies in the degree of dissociation into ions. Each substance has a "dissociation constant," which differs with the individual substance. This means that not all substances in solution divide into their respective ions to the same degree.

For example, in an acetic acid solution, there are more of the combined hydrogen acetate molecules than there are of the hydrogen and acetate ions. Hence, acetic acid is a weak acid.

On the other hand, in a hydrochloric acid solution, more of the substance is in the form of hydrogen and

chloride ions than in the form of hydrogen chloride particles. This, then, is a strong acid.

What is pH?—Even distilled water breaks up slightly into its respective ions. The number of hydrogen ions here equals 0.0000001 grams per liter. This is expressed in terms of the power of ten, thus: $[H^+] = 10^{-7}$. Likewise, the hydroxyl ions also equal $\frac{1}{10,000,000}$

gram-molecules per liter, or, $[OH^-] = 10^{-7}$. In other words, the two opposing ions balance, and the solution is neutral.

In view of the large figures involved, and the resultant confusion, Sørensen has introduced the term pH to simplify the nomenclature. By this method, the ten and the minus sign are omitted, leaving only the exponent. Thus, water has a pH of 7.

The total dissociation is always 10^{-14} . Therefore, as the hydrogen ions increase, the hydroxyl ions decrease proportionately. For this reason, we are able to omit consideration of the hydroxyl ions and mention only the hydrogen ion concentration, remembering that the total is always 14. The pH, therefore, is based only on the hydrogen ion concentration.

To summarize, a pH of greater than 7 is alkaline, or basic, while a pH of less than 7 is acid. The farther away from 7, the more acid or alkaline.

pH of the Body Fluids.—Normally, the pH of the blood is confined within the limits of 7.3 and 7.5. The maximum range of toleration, however, is between 7.0 and 7.8 (1).

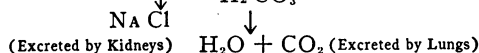
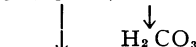
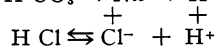
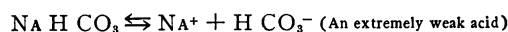
Acidosis and Alkalosis.—The body fluids, therefore, are always slightly alkaline. A pH of 7.5 or over is called an "alkalosis" or "hyperalkalinity," while a pH less than 7.3 is variously termed "acidosis," "hyperacidity," or "hypoalkalinity." While the latter term more correctly defines the condition, "acidosis" is more popular in the literature and is most widely used by clinicians. For this reason we shall confine ourselves to the terms "alkalosis" and "acidosis," remembering that at no time does the blood give an acid reaction.

Buffer Salts.—The manner in which the body fluids are kept physiologically neutral is of great interest and importance. Briefly, this is accomplished in three ways: by the action of buffers, or tampons (those compounds that resist changes in pH when an acid or alkali is added); by respiration; and by excretion (4). We are particularly interested in the buffer salts of the body, which are comprised of both organic and inorganic substances (3).

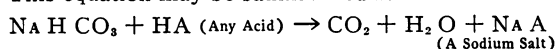
The principal organic buffers are the proteins, which, because of their amphoteric properties, combine equally well with acids or bases. The dual character of this type of buffer is due to the protein molecule, which contains both amino (NH_2) and carboxyl ($COOH$) groups. The amino group functions as an alkali and combines with acids, whereas the carboxyl group assumes acidic properties and combines with bases.

Graphically, the actions of the various types of inorganic buffer may be shown in the form of chemical equations, as follows:

1. Bicarbonates



This equation may be summarized as follows:



* Editor's Note.—The National Institute of Health, successor to the Hygienic Laboratory of the United States Public Health Service, which in turn operates as one of the bureaus or divisions of the Treasury Department of the United States, came into existence through an act of Congress, approved May 26, 1930. One of the publications brought out by the National Institute is a small booklet on "The Acid-Base Balance of the Body." Part One of that booklet is here reprinted because it is more or less pertinent to the California Medical Association prize paper by Dr. Harold L. Thompson, which also appears in this issue under the title, "Resection of the Pylorus." (See page 383.)

